UTAH GEOLOGICAL AND MINERAL SURVEY

GUIDELINES FOR EVALUATING SURFACE FAULT RUPTURE HAZARDS IN UTAH

by
The Utah Section of the Association of Engineering Geologists

These guidelines have been compiled to assist geologists in the investigation of possible hazards due to surface fault rupture and to enable reviewers to evaluate the thoroughness of such investigations. The guidelines were developed by the Guidelines Committee of the Utah Section of the Association of Engineering Geologists for the purpose of protecting the health, safety, and property of the people of Utah. Previously published guidelines for the State of California (California Division of Mines and Geology, 1975; Slosson, 1984) were used as models. The guidelines do not include systematic descriptions of all available techniques or topics, nor is it suggested that all techniques or topics be utilized on every project. Variations in site conditions and purposes of investigations may require more or permit less effort than is outlined here. All elements of these guidelines should be considered during the preparation and review of engineering geologic reports.

Future faulting generally is expected to recur along pre-existing faults (Bonilla, 1970, p. 68); the development of a new fault or reactivation of a pre-Quaternary fault is relatively uncommon and generally need not be a concern in site development for typical facilities. Generally, the more recent the faulting, the greater the probability of future faulting (Allen, 1975; Ziony and others, 1973). Regional and urban earthquake hazards and risk in Utah are reviewed by Hays and Gori (1984).

The evaluation of future fault rupture hazards involves careful application of skills and techniques not commonly used in other engineering geologic investigations (trenching, absolute dating). Many active faults are complex, consisting of multiple breaks which may have originated during different surface-faulting events. To accurately evaluate the potential hazards due to future surface fault rupture, the geologist must determine:

I. Fault Locations

This involves locating and accurately mapping all tectonic features at the site, at a scale large enough to be used for site planning (1 inch = 200 feet).

II. Nature of Deformation

Surface deformation over active faults may involve single large displacements, multiple small displacements, monoclinal flexure, backtilting, or a combination of all of these (see Bonilla, 1982). The way in which the surface deforms influences the type and degree of risk posed to various types of structures.

III. History of Fault Ruptures

The absolute age of past displacements should be obtained over as long a period of geologic time as possible. Two key measurements are: 1) the age of latest faulting, and 2) the average recurrence interval between surface-rupturing events.

Few structures intended for human occupancy are designed to withstand surface rupture of their foundations without serious damage. If such a structure is sited astride an active fault, the subsequent fault rupture hazard cannot be mitigated unless the structure is relocated. Therefore, the scope of the investigation depends on not only the complexity and economics of the project, but also on the level of risk acceptable for the proposed development. Because of variability in the risk and in the complexity of site geology, not all investigative techniques described here need to be or can be employed in evaluating a single site. The guidelines provide a checklist for preparing complete and well-documented reports.

Regardless of the size of the project (single-family residence vs high-rise building) the conclusions drawn from geologic data must be consistent and unbiased, and must not tie to the design life or perceived economics of the project. Recommendations must be clearly separated from conclusions, since recommendations are not solely dependent on geologic factors.

Suggested Outline for Reports Evaluating Surface Fault Rupture Hazard

The following subjects should be addressed in any geologic report on faults. Some of the investigative methods listed below should be extended well beyond the site being investigated. Not all of the methods identified will be useful at every site.

A. Purpose and Scope of Investigation

B. Geologic and Seismotectonic Setting

1. Regional Geology
2. Tectonic Setting
   a. Location and style of known active faults (see Anderson and Miller, 1979; Nakata and others, 1982).
   b. Major earthquakes in historic time (see Arabasz and others, 1979).

C. Site Description and Conditions - Include information on depth to ground water, geologic units, graded and filled areas, vegetation, existing structures, and other factors that may affect the choice of investigative methods and the interpretation of data

D. Office Methods of Investigation

1. Review of published and unpublished literature, maps, or records concerning geologic units, faults, ground-water barriers, and other factors.
2. Stereoscopic interpretation of aerial photographs or other remotely sensed images to detect fault-related topography, soil and vegetation contrasts, and other lineaments of possible fault origin. Low-sun-angle photographs are particularly useful for fault scarp recognition (see Cluff and Slemmons, 1971).
3. Personal communication with those who have first-hand knowledge about geologic conditions or pertinent land-use history of the site.

E. Field Methods of Investigation

1. Surface
   a. Geologic mapping - distribution, depth, thickness and nature of geologic units, both surficial and bedrock.
   b. Location and relative ages of tectonic surface features, including fault scarps, sag ponds, aligned springs, offset bedding, disrupted drainage systems, offset ridges, faceted spurs, locations of zones of crushed rock (fault breccia). Relationships with dated alluvial terraces or shorelines (Currey, 1982) may yield indication of age. Surface topographic profiling of fault scarps may permit an age estimate if scarps result from a single rupture event (Nash, 1980; Hanks and others, 1984) or may show evidence of multiple events (Wallace, 1977).
   c. Locations and relative ages of other possibly earthquake-induced features caused by lateral spreading, liquefaction, or settlement. Locations of slope failures should be noted, although they may not be conclusively tied to earthquake causes.
2. Subsurface
   a. Trenching or other excavations across features of suspected tectonic origin. A detailed trench log should be prepared at a scale of 1:60 or larger showing geologic units. soil profiles, and all discontinuities (unconformities, fractures, shear zones, fault planes, sand or rubble-filled cracks, burrows). The position of all samples used for absolute dating must appear on the log. Systematic photographs should be taken to document the presence or absence of tectonic features. Because the location of trenches is critical in obtaining

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tectonic or stratigraphic data, investigators are encouraged to discuss trench location, orientation, depth, and length with reviewers in advance of excavation. Multiple trenches, if needed, should be excavated concurrently, not sequentially. All critical excavation should be left open for at least 48 hours after logging is completed to allow access by reviewers. Fencing, posting, and shoring of all the trenches is strongly recommended (see Woods, 1976).

b. Absolute dating to determine timing of past surface rupture events. Methods commonly used for Quaternary deposits are reviewed by Colman and Pierce (1977, 1979) and McCalpin (1986). Samples should be collected which most tightly bracket the time of faulting, e.g., from the youngest parts of faulted units and from the oldest parts of unfaulted units.

c. Borings and test pits to collect data on geologic units, fault-plane geometry, and ground-water elevations. Data points must be sufficient in number and adequately spaced to permit valid correlations and interpretation.

3. Geophysical investigations. These are indirect methods that require knowledge of specific geologic conditions for reliable interpretation. Geophysical methods alone never prove the existence or absence of a fault, nor can they assess the recency of activity. Types of equipment and techniques used should be described. Methods commonly include seismic refraction, seismic reflection, electrical resistivity, gravity, magnetic intensity, and ground penetrating radar.

4. Other investigations; where special conditions or requirements for critical structures demand more intensive investigation.
   a. Aerial reconnaissance overflights.
   b. Geodetic and strain measurements.
   c. Microseismicity monitering.

F. Conclusions

1. Locations of mapped faults; style of associated displacement and age of past surface rupturing events.
2. Anticipated amount and pattern of earth displacements in the next probable surface-faulting event; delineation of areas of high risk.
3. Probability or relative potential for future surface displacements. The likelihood of future faulting may be estimated from the recurrence intervals between past events, plus the age of latest faulting, or from slip rates and amount of anticipated earthquake slip determined for the specific site or from an identified fault segment which includes the site (for Wasatch fault segments, see Anderson, in press).
4. Comparison of conclusions developed from site data with previous interpretations on the same fault trace or segment.
5. Degree of confidence in and limitations of data and conclusions.

G. Recommendations

1. Recommended building restrictions or use limitations within any designated high-risk areas.
   a. Setback distances from hazardous faults. Most Utah local governments currently have no laws dictating minimum setback. Therefore, justification must be clearly provided for recommended setback distances (see McCalpin, 1987).
   b. Restrictions arising from causes other than discrete surface rupture (e.g., ground tilting, induced mass movements).
2. Risk evaluations relative to the proposed development. Any probabilistic estimates of fault rupture within the design life of the development should be supported with assumptions used and probable error ranges.
3. Need for additional studies.

H. References

1. Literature and records cited or reviewed.
2. Aerial photographs or images interpreted - list type, date, scale, source, and index numbers.
3. Other sources of information, including well records, personal communications. and other data sources.

I. Illustrations - These are essential in understanding the report and reducing the length of the text.

1. Location map - identify site locality, significant faults, geographic features: 1:24,000 scale recommended.
2. General geologic map - shows geologic setting of site, geologic units, faults, other geologic structures, geomorphic features, lineaments, springs, epicenter of historic earthquakes of M>4.1:24.000 scale recommended.
3. Site map - combines a detailed. large-scale geologic map of the site with pertinent development-related data (site boundaries, existing and proposed structures, graded areas, streets, exploratory trenches, boring locations, geophysical traverses, and other data). Site geology must correlate with the regional geologic map but should provide refined data on surficial deposits. Recommended scale of 1 inch equals 200 feet or larger (1:24,000).
4. Geologic cross sections, to extend to the depth of exploratory borings or foundation elements, whichever is greater; same horizontal scale as the site map.
5. Logs of exploratory trenches or borings. Trench logs in particular should show all relevant detail at a scale of 1:60 or larger within zones of suspected deformation; no vertical exaggeration.
6. Geophysical data and its geologic interpretation.
7. Photographs - of scarps, trenches, samples, or other features which enhance understanding of the pertinent site conditions.

J. Appendix - Supporting data not included above (e.g., water well data).

K. Signature of Investigating Geologist - The report must be signed by the engineering geologist who conducted the investigation. The State of Utah currently has no statutory definition of an engineering geologist; however, some local governments do define the minimum qualifications of geologists who can submit reports. Current registration as a geologist in another state may be used in support of demonstrating qualifications.

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